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RELATIONSHIP BETWEEN EXTINCTION RESPONDING AND CONDITIONING REINFORCEMENTS

by

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Abstract

The purpose of this investigation was to ascertain to what extent "resistance to extinction" is a function of conditioning reinforcements when spurious responses (accidental bar-presses due to activity) are not recorded. If there should occur a positive correlation between "input" (conditioning reinforcements) and "output" (extinction responses), further analysis of extinction data was planned in order to establish: (1) when during extinction maximum contingency between "input" and "output" occurs, and (2) how long this contingency continues.

Pretraining (approximately 50 pellets) was given to 120 male rats so that each subject earned one reward by pressing an inconspicuous lever. Each subject was then trained until 0, 4, 12, 36, 88, or 108 reinforced bar-presses had occurred. Extinction for either 2 or 4 hours occurred on the following day.

Since the operant response level (response level of control subjects) was virtually zero, the object of recording only responses due to learning was apparently achieved. Number of extinction responses did reveal a reliable increase as number of conditioning reinforcements increased, from zero to 4 to 12. Additional reinforcements (from 12 to 108) did not reliably increase the number of extinction responses. The obtained differentiation between groups occurred primarily during the first 6 minutes of extinction, as indicated by measures of number of responses per minute.

The data emphasize the importance, to assessing the effects of number of reinforcements, of measures very early in extinction. They question the usually assumed relation between persistence of a

habit and number of conditioning reinforcements. Since there occurred during extinction a temporary burst of responding in proportion to number of reinforcements, except for the maximum-reinforcement group, an attempt was made to relate these findings to the constructs of inhibition and frustration. An apparent reduction in resistance to extinction in the highest-reinforcement group should be investigated by an extension of the reinforcement parameter considerably beyond 108. If extinction responding should be found to relate to number of reinforcements in a non-monotonic fashion, it might be necessary to re-examine the practice of using resistance to extinction as a measure of habit strength.

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Table of Contents

| | Page |
|--|------|
| Abstract | iii |
| Acknowledgements | v |
| Table of Contents | vi |
| List of Tables and Figures | vii |
| Introduction | |
| General and Theoretical Considerations | 1 |
| Purpose | 8 |
| Method | |
| Apparatus | 10 |
| Subjects | 10 |
| Procedure | 10 |
| Results | 13 |
| Discussion | 19 |
| Summary | 28 |
| References | 29 |

List of Tables and Figures

| Tables | Page |
|---|------|
| 1. Summary of trend analysis of group response rates during two hours of extinction | 13 |
| | |
| Figures | |
| 1. Mean response rates (responses/time) during two hours each of extinction and spontaneous recovery; comparisons of means by Duncan's New Multiple Range Test -- means underscored by the same line do not differ significantly from those not so underscored | 14 |
| 2. Mean response rates (responses/time) within recorded extinction intervals as a function of time; comparisons of means by Duncan's New Multiple Range Test -- means falling within the same enclosure do not differ significantly from each other but do differ from means outside that enclosure | 15 |
| 3. Mean cumulative number of responses during various intervals of extinction as a function of number of reinforcements | 16 |

Introduction

General and Theoretical Considerations

A technique which is frequently used for investigating simple learning processes is referred to as operant conditioning. An organism responds to, or "operates on" its environment and those responses which procure reward, or reinforcement, become strengthened, i.e. response frequency or probability increases. For example, a white rat, when placed in a box having a depressable bar attached to one of its walls, will most likely investigate it and eventually press it. If the rat is rewarded immediately with a piece of food following its bar-press response, it is more likely that the bar will be pressed again, with reinforcing effects accumulating until a persistent response tendency develops. In other words, the rat acquires a bar-pressing habit. Once reinforcement no longer follows the bar-presses, the strength of this response, or the frequency with which it occurs, diminishes. This process of emitting a previously rewarded response without reinforcement is termed extinction, and is a common measure of the strength of a habit.

Habit strength is generally thought to increase monotonically as the number of reinforced acquisition trials increases. While this notion is implicit in the statements of many investigators (Williams, 1938; Perin, 1942; Campbell, 1959; Harris and Nygaard, 1961), it is stated explicitly by Hull (1943) who conceives of it as a negative growth function of the number of reinforcements. Because habit is an intervening variable (Hull considers it a neurological process), it cannot be measured directly, but must be inferred from antecedent operations and resulting behavior changes. One of the most common ways of expressing it is in terms of the progressive decrease in responding during

extinction, measured variously as changes in response latency, and time or number of responses to an extinction criterion. In Hull's system, habit strength interacts with a number of other factors to determine the strength of the subject's tendency to perform the learned response, i.e. reaction potential, which presumably is reflected in observable behavior, and which has been represented as follows:

$$S^E_R = D \times V \times K \times J \times S^H_R - I_R - S^I_R.$$

Each of these factors is in turn a function of one or more antecedent variables. D, drive, is a function of period of deprivation; V, stimulus intensity dynamism, is a function of stimulus intensity; K, incentive motivation factor, is a function of w or magnitude of reinforcement; J, delay in reinforcement, is a function of t, or time of delay; S^H_R , habit strength, is a function of N_G , or number of reinforcements; I_R , reactive inhibition, is a function of work or number of responses made; S^I_R , conditioned inhibition, is a habit of "not responding" which depends upon its reduction of the need for rest (I_R) which increases with the number of non-reinforced trials.

Since our chief concern is with the last three factors, the remaining ones will be treated as a constant. Consider first S^H_R . In determining the presumptive quantitative nature of the functional relation of habit or S^H_R , to number of reinforcements, N_G , Hull has drawn upon empirical data such as that of Youtz (1938a), Williams (1938), and Perin (1942), who trained large numbers of rats to bar-press for a food reward. Various groups were allowed different numbers of such rewarded acquisition trials, then all subjects were extinguished to a criterion of extinction of 5 minutes without a response. In Perin's study, response latencies, extinction time, and number of non-rewarded trials

to reach the criterion were measured. All of these three measures indicated that extinction responding was stronger for groups which had experienced greater numbers of reinforced training trials. This relation, however, was apparent only up to a point, i.e. about 90 reinforcements. As number of reinforced trials increased, differences in habit strength decreased and approached an asymptote. In other words, the ratio of non-reinforced responses to number of previous reinforcements decreased progressively, with this function forming a curve with negative acceleration. From these observations, as well as from others involving conditioning of GSR, nonsense syllables etc., Hull formulated his Law of Habit Formation. "If reinforcements follow each other at evenly distributed intervals, everything else constant, the resulting habit will increase in strength as a positive growth function of the number of trials according to the equation,

$$S_{H_R} = 1 - 10^{-.0305N},$$

where N is the total number of reinforcements from Z." (Hull, 1952, p. 6).

The basic principle of the simple positive growth function was chosen as an appropriate algebraic expression of habit because it is known to approximate closely a large number of observable empirical relationships in many types of biological situations involving growth and decay. Thus, Hull's conception of habit formation is summarized generally as follows: "the amount of growth resulting from each unit of growth opportunity will increase the amount of whatever is growing by a constant fraction of the growth potentiality as yet unrealized." (Hull, 1943, p. 114). More specifically, suppose a maximum habit strength is 100 units and the growth constant in a given reinforcement

situation is $1/10$. Then generation of $1/10 \times 100 = 10$ units of habit on the first trial leaves 90 units of potential growth. The habit increment resulting from the second reinforcement must be $1/10 \times 90 = 9$ units, leaving 81 potential units; on the third trial $1/10 \times 81 = 8.1$ units are subtracted. This process can be repeated as many times as there are successive reinforcements.

Effective reaction potential or $\bar{S}E_R$, i.e. the potential actually available for the evocation of action is $S E_R$ minus the inhibitory potential. The latter is the concept by which Hull explains experimental extinction. He begins with the hypothesis that, "Whenever any reaction is evoked in an organism there is left a condition or state which acts as a primary negative motivation in that it has an innate capacity to produce a cessation of the activity which produced the state." (Hull, 1943, p. 278). Hull calls this state reactive inhibition, I_R , another logical construct which is observable through its effect upon response measures of positive reaction potentials.

According to Hull, every repetition of a response generates an increment in I_R which dissipates with the passing of time. Because of the negative motivational character of I_R anything which reduces this need to cease action should be reinforcing. Thus cessation of action becomes conditioned to whatever stimuli may be present, forming a genuine habit of "not responding", i.e. conditioned inhibition ($S I_R$), which combines physiologically with any I_R present on a given trial to subtract from $S E_R$ and to determine the effective reaction potential $\bar{S}E_R$. Because $S I_R$ is a relatively permanent habit, spontaneous recovery of reactive potential upon dissipation of I_R is not complete.

Extinction is described by Spence and by Amsel in terms of

inhibition of the learned instrumental response by a frustration-produced response which becomes stronger than the instrumental one. Spence's theory of extinction may be summarized as follows:

1. Non-reinforcement of a previously reinforced response results in an emotional ("anger") state or response which is designated by Amsel as r_f , and is assumed to contribute to the general drive level, D , of the organism.

2. Occurrence of r_f is assumed to depend upon the prior development in instrumental reward learning of the expectation of reward; i.e. the prior development of a fractional anticipatory consummatory reaction r_g the strength of which bears a positive relation to the strength of r_f .

3. Again following Amsel, r_f not only would occur at the end of the response chain but, like the fractional anticipatory goal reaction, would become conditioned to stimulus events earlier in the response chain.

4. It is assumed that during experimental extinction the frustration-aroused response r_f through its own response-produced cues, s_f , tends to elicit previously learned or unlearned overt responses, some of which are incompatible with the learned instrumental response. With repetition of unreinforced trials, these competing responses would gradually become more strongly conditioned to the situation and consequently would compete more and more successfully with the learned response sequence, producing the typical curve of decrement in response strength. (Spence, 1960, p. 98).

A picture of habit strength unlike any of the above has been presented by several recent studies which have failed to show extinction

responding as an increasing monotonic function of increasing numbers of conditioning reinforcements. Some of these have in fact showed the extinction function to take the form of an inverted U. Finger (1942a), comparing number of running responses, in an elevated runway, of subjects extinguished immediately following 16 or 8 rewarded acquisition trials, found the most rapid initial increase in latencies, and fewer total responses in the 16-group than the 8-group. These differences were not observed when he delayed extinction for 24 hours (1942b).

A similar runway response was used by Mote (1944) to test a larger range of the reinforcement parameter. Latency (starting time) measures at the end of acquisition differentiated only 3-reward subjects from others who had had either 12, 18, or 24 rewarded acquisition trials. Extinction curves of steeper slopes with increasing numbers of rewarded acquisition trials suggested a positive correlation between rate of increase of response latencies and number of previously rewarded trials, i.e. more rapid extinction following greater numbers of reinforcements.

Mote and Finger (1943) also found that 16- and 32-reward groups extinguished more rapidly than those with 4 or 8 previous rewards; and observations by Youtz (1938b) over several extinction sessions confirmed these trends.

North and Stimmel (1960) allowed rats 45, 90, or 135 reinforced acquisition trials in a straight runway. In 60 extinction trials, the starting and running times of the 90- and 135-reward groups increased more rapidly than those of the 45-reward group, leading the authors to postulate that overlearning facilitates extinction, producing a non-monotonic relation between resistance to extinction and number

of conditioning reinforcements.

These experiments tend to support Mote's suggestion (1944) of a maximum "habit strength" resulting from a relatively small number of rewarded acquisition trials. There is some indication that, with a more extensive sampling of the reinforcement parameter, there is a range of number of reinforcements which is optimal with respect to strength of that response tendency, and reinforcement beyond this range again decreases the probability of that response in extinction.

Some support to this idea stems from the results of Murillo and Capaldi (1961) with human subjects (undergraduates) tested in the Wisconsin General Test Apparatus. "Learners" were defined as those subjects which achieved 7 consecutive correct responses before extinction. Considering the entire sample, resistance to extinction decreased with increased training, but this trend seemed to be due to the behavior of the learners only. The non-learners showed increased resistance to extinction with increasing reinforcements. The authors suggest that resistance to extinction appears to increase with increased training only up to the point where no overlearning has occurred, and that it decreases with additional training after learning has occurred, with the resulting curvilinear function.

It seems clear that the precise quantitative nature of the relation between habit strength, measured as resistance to extinction, and number of reinforced acquisition trials has not been established satisfactorily. A subject will press the bar even when no reinforcement for it has been forthcoming. Schoenfeld, Antonitis, and Bersh (1950) observed the unconditioned response rate of both hungry and thirsty white rats in a bar-pressing apparatus. Given 1-hour sessions each day,

the animals exhibited a consistent decrease in mean number of responses and degree of variability. After only 2 or 3 daily sessions, a fairly stable operant level was reached. Within each experimental hour also, extinction-like trends were apparent. Such observations tend to suggest that some of the instrumental responses made during extinction are not strictly due to learning, but are accidental, i.e. part of an unconditioned operant reserve. Perhaps it would be feasible to obtain a more unequivocal measure of the effect of reinforcements per se with an apparatus designed so that fewer responses would be recorded during the subject's random movements.

Further, most of the studies investigating extinction responding following varied numbers of reinforcements have used criteria of extinction, and have not observed the nature of the relation between strength of extinction responding and number of conditioning reinforcements over intervals other than those which met some rather arbitrary extinction criterion. Presumably, whatever relation was found at that time was considered to be the representative function, without concern for possible changes over time.

Purpose

The present study was undertaken to delineate the effects of various numbers of initial conditioning reinforcements throughout a lengthy period of extinction. Data from the previously reviewed research have indicated that subjects experiencing large numbers of reinforcements in comparison with groups receiving few, emit a greater number of extinction responses. Therefore, some kind of contingency was expected between "input" - number of reinforcements - and "output" - extinction responses. During extinction, successive samples of

responding were obtained at different time intervals in order to establish when and for how long contingencies were manifest. It would appear that this function - the one characterized by the highest "input-output" contingency - has the most critical implication for hypothetical theory construction.

Method

Apparatus

The equipment consisted of two Skinner boxes (9 x 14 x 12 inches) with a $\frac{1}{4}$ "-wide clear plastic bar protruding approximately $\frac{1}{2}$ ", and a 1-inch wide metal food tray about an inch below and 2" to one side of it. The box was enclosed within a chamber which, when closed, eliminated visual stimulation and dampened extraneous sound. A magnetic counter in the next room cumulatively counted the number of lever presses.

Subjects

The experimental animals were 120 male albino rats of the Sprague-Dawley strain. 48 were experimentally naive; 72 had been used in an experiment where activity measures were taken. Their ages ranged from 70 to 120 days.

Procedure

Animals were kept in groups of 10 to 20 until pretraining, when they were given separate living cages and assigned to reinforcement groups by restricted randomizations to insure that each condition was represented in all replications of the experiment. Assignment to the 2 Skinner boxes was similarly randomized within each replication. The same box was used throughout the experiment for a given subject.

Taming and habituation of naive subjects involved 7 days - 4 days, at 10 minutes per day, of handling and exploration of table tops, and 3 days on which subjects were placed in a closed rectangular box (similar to that enclosing each Skinner box) until they had eaten about 20 small food pellets scattered about on the floor. The first four days of taming were eliminated for subjects which had previously been handled

in the activity experiment.

The day following completion of taming and habituation, each subject was given 20 small pellets in the Skinner box, one at a time. The first 10 were delivered without the relatively loud click of the delivery mechanism, by manual rotation of the pellet dispenser; the remaining 10 were delivered automatically by the closing of a switch to activate the pellet dispenser.

Training by successive approximations began on the following day. Each rat was rewarded for responses which brought him progressively closer to the bar, until one bar-press was emitted.

On the day after pretraining, each subject was conditioned with one of the following numbers of rewarded bar-presses: 0, 4, 12, 36, 88, 108.¹ To hasten bar-pressing, 3 to 6 "free" pellets were given initially. Where this proved insufficient to initiate pressing within about 15 minutes, or if conditioning did not occur after an initial bar-press, the subject was discarded. Control subjects were given 5 "free" pellets, but not allowed to press the bar.

Extinction for 2 or 4 hours (N=78 for 4-hours) took place the next day in the Skinner box with the dispenser disconnected so that bar-pressing no longer produced reward. On the day after extinction, 66 of the subjects were reintroduced to the apparatus for a 2-hour test of spontaneous recovery. Cumulative numbers of responses during extinction and spontaneous recovery were recorded at the following intervals:

¹ With the exception of the first 38 subjects, this conditioning was carried out with the box closed. t tests indicated no significant differences in the mean number of responses made by subjects which had been conditioned with lid up and with it down.

1 min., 3, 6, 9, 18, 27, 40, 60, 80, 100, 120 min. (two series comprised the 4-hour periods).

Deprivation time was measured from the end of a $1\frac{1}{2}$ -hour feeding period. It was 16 - 20 hours during pretraining and conditioning, and 22 hours during extinction and spontaneous recovery.

Results

Since the operant response level was virtually zero, the object of recording only responses due to learning was apparently achieved.

The results of a trend analysis, summarized in Table 1, show that extinction responding was influenced by number of conditioning reinforcements ($p < .005$). Fig. 3 shows cumulative number of extinction responses at different times for each group, and Fig. 1 shows group mean response rates (responses/time) over the entire 2-hour extinction period. In general, increasing numbers of conditioning reinforcements resulted in increasing numbers of responses per minute, the highest response rate being that of the 88-reinforcement group. The significance of the difference between groups was tested by means of Duncan's New Multiple Range Test, illustrated in Fig. 1. Groups which are underscored by the same line were not significantly different from each other but were different from all groups which are not so underscored ($p < .01$). No differences occurred among the four high-reinforcement groups (12 - 108) which all differed reliably from the control group and from the 4-reinforcement group, with the exception of the 12-reinforcement group. The 12- and 4-reinforcement groups did not differ reliably.

Table 1. Summary of trend analysis of group response rates during two hours of extinction.

| Source of variation | Mean Square | Degrees of freedom | F |
|-----------------------|-------------|--------------------|--------|
| Reinforcements | 143.06 | 5 | 19.23* |
| Error | 7.44 | 114 | |
| Time | 250.01 | 10 | 73.10* |
| Reinforcements x time | 17.48 | 50 | 5.11* |
| Error | 3.42 | 1140 | |

* $p < .005$

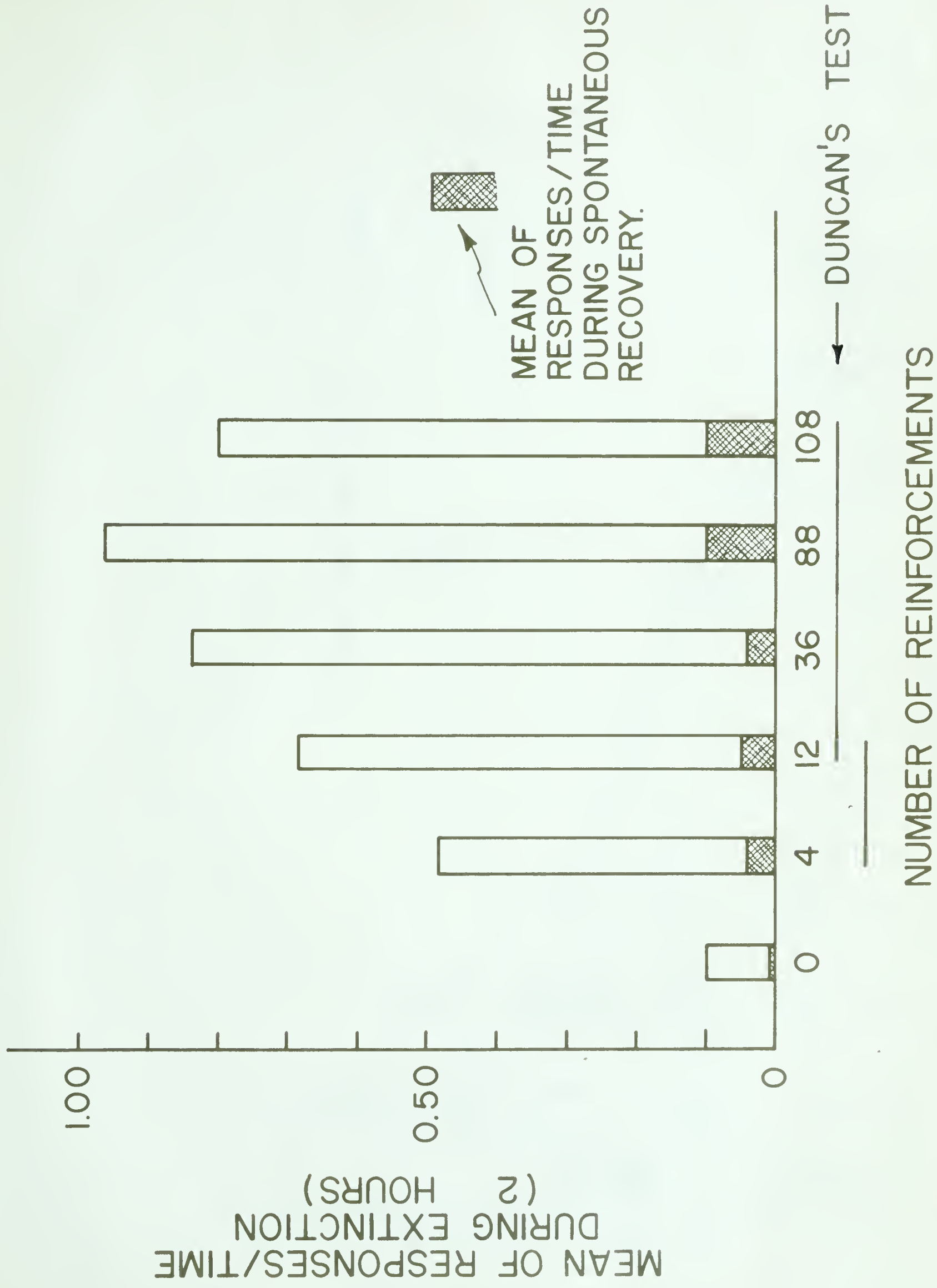


FIG. 1

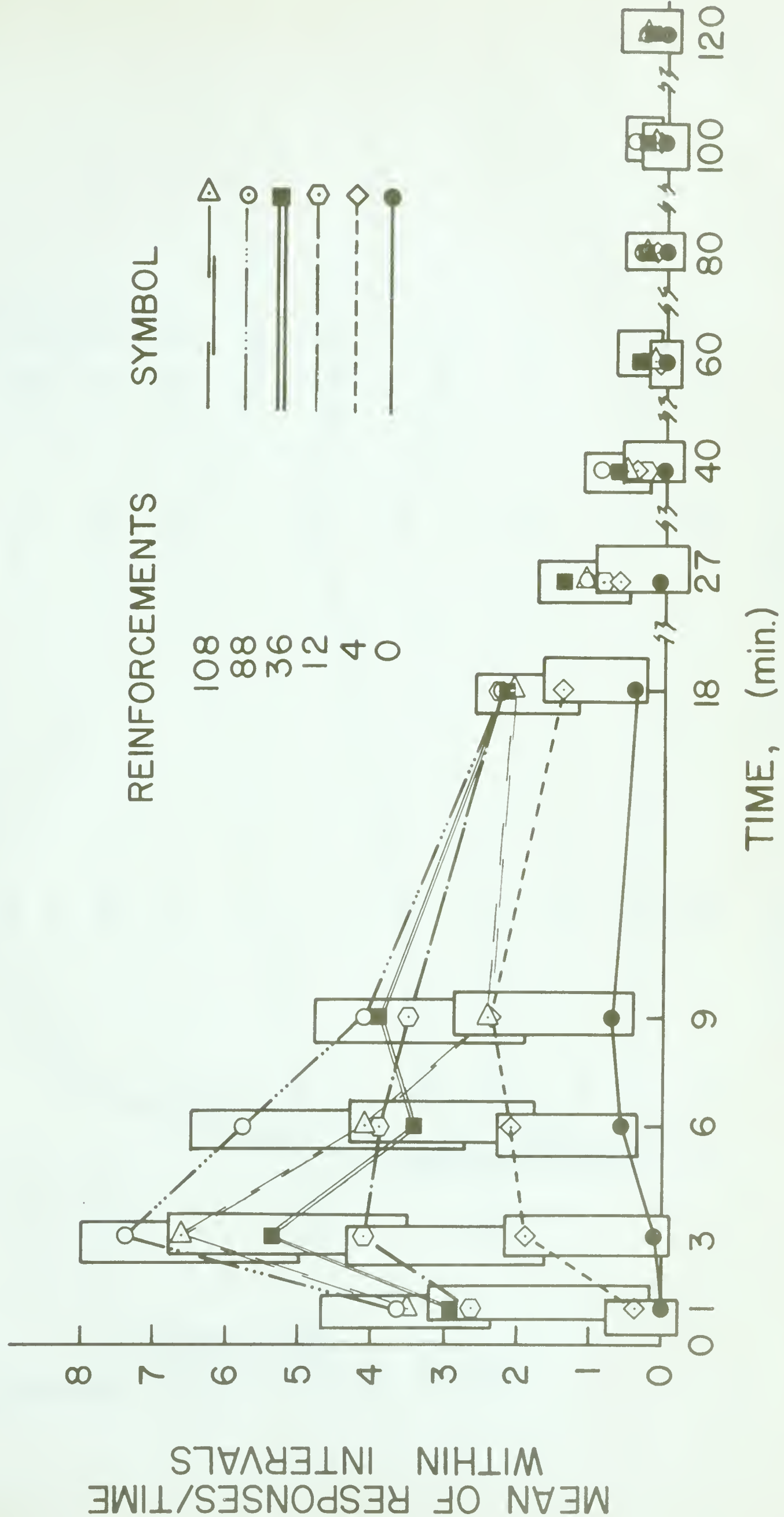
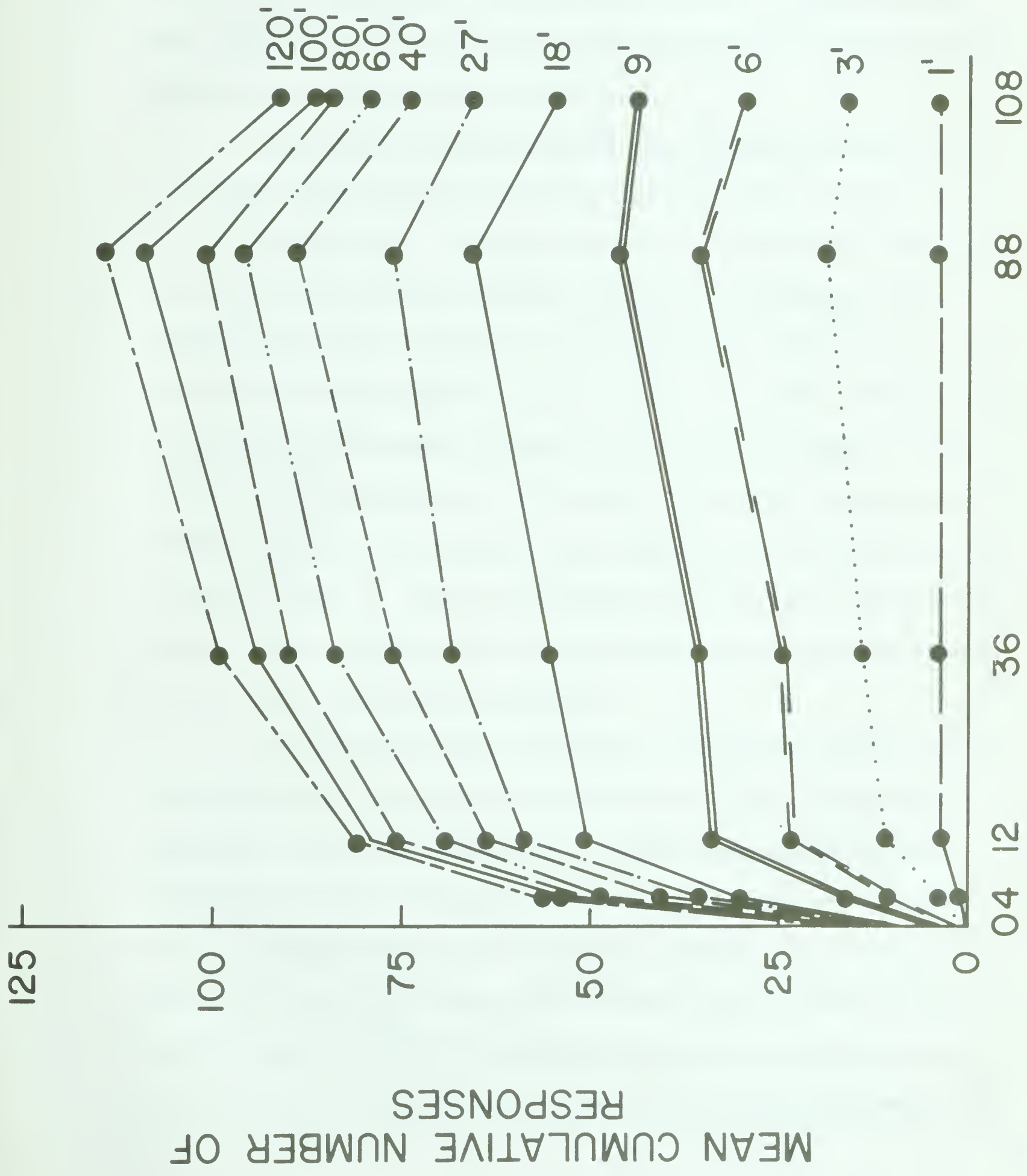


FIG. 2



NUMBER OF REINFORCEMENTS

FIG. 3

In Fig. 1, mean response rates for each group during a 2-hour test of spontaneous recovery on the day following extinction show that the 88- and 108-reinforcement groups still exhibited a slightly stronger response tendency than the others. No statistical treatment was applied to the spontaneous recovery data because response rates of most of the subjects in every group were zero so that the group distributions were markedly skewed positively.

The effect of reinforcements upon extinction responding is illustrated again in Fig. 2 where mean response rates of each group are plotted over time. A one-way analysis of variance of responding in each recorded interval indicates that the reinforcement effect remained significant throughout the first hour of extinction ($p < .005$ for the first 27 min. and $p < .01$ thereafter to 60 min.). However, not all comparisons of groups adjacent to each other in number of reinforcements were significant. The results of multiple comparisons, by Duncan's Test, of mean response rates during each extinction interval are shown in Fig. 2. Group means which fall within the same enclosure did not differ significantly from each other ($p < .01$) but did differ from all means outside that enclosure.

It is apparent that significant differences between experimental groups were found early in extinction. While there was no significant difference between the 4-reinforcement group and the controls at any time, the mean response rate of the 4-reinforcement group was consistently above that of the controls. The greatest differences occurred in the interval between 1 and 3 minutes, when the 4-reinforcement group differed reliably from all other experimental groups except that with 12 reinforcements. The 12-reinforcement group

in turn differed significantly from the 88-reinforcement group, but not from any of the other experimental groups. At no other time in extinction (i.e. only in this 2-minute interval between 1 and 3 min.) were there any significant differences among the four groups with 12 - 108 reinforcements. Beyond 6 minutes, the 4-reinforcement group also ceased to differ from any other group. During the rest of extinction, gradually fewer of the experimental groups differed reliably from the control group so that all response rates were similarly low for most of the time beyond 60 minutes.

The decline in response rate during the course of extinction was reflected in the significant time effect ($p < .005$). A significant reinforcement x time interaction indicated that the change in rate of response over time differed amongst the groups, as seen in the different slopes of the extinction curves over time. The curve for the 4-reinforcement group reached its peak at 9 min. and was generally flatter than those of the other experimental groups which reached their peaks earlier (at 3 min.).

Separate trend analyses were performed, comparing groups two at a time. The 4-reinforcement group differed reliably from other reinforcement groups in the shape of its response rate curve over time, i.e. there was a significant reinforcement x time interaction ($p < .005$) between the 4-reinforcement group and each other group. This held true for the control group too, but none of the other reinforcement group comparisons produced a significant interaction effect. It seems that the reinforcement x time interaction arose mainly from the different slopes of the response rate curves of the controls and the 4-reinforcement group on the one hand, and the other four groups (12 - 108 reinforcements) on the other.

Discussion

Examination of the functions of resistance to extinction shows that the general result of increasing the number of conditioning reinforcements was an increase in the number of instrumental responses emitted during extinction. This was supported by a trend analysis of group response rates over time and by one-way analyses of variance of response rates in each successive measured interval. However, the extent of the contingency varied during different intervals. In general, it was greatest very early in extinction and decreased gradually with time. Thus, the extinction function observed here represented a steeper growth with small numbers of reinforcements (0 - 12) than those of Williams (1938) and Perin (1942) which exemplified more closely Hull's S^H_R growth curve.

Duncan's New Multiple Range Test (Edwards, 1960), simultaneously comparing mean response rates, differentiated a greater number of groups in the interval between 1 and 3 minutes than in any other interval during which responding was recorded. This was the only interval in which any reliable differences between pairs of groups were found among the four highest-reinforcement groups (12 - 108). These four groups seemed to differ as a whole from the remaining experimental group (4 reinforcements) which did not differ reliably from the control group in any single interval. Similarly, reinforcement x time interaction, indicating different slopes for response rate curves, was significant in the comparisons of the 4-reinforcement group with each other group, though not in any inter-group comparisons among those which had experienced 12 - 108 reinforcements. The reinforcement x time interactions involving comparisons of the control group with each of the

other groups also all were significant.

Changes, over time, in the characteristics of extinction responding as a function of number of reinforcements have not been considered in theoretical discussions of habit strength. More commonly, response persistence to some criterion of low response strength (e.g. 5 min. with no response), following continued nonreward, has been taken as an index of habit strength. Hull (1943) considers that habit strength increases monotonically as a negative growth function of number of reinforcements, and that this is reflected in the increasing numbers of nonrewarded responses which will be emitted before a criterion of extinction is reached by organisms which have experienced increasing numbers of reinforced conditioning trials. According to Hull, reinforcement of a response results in its becoming more strongly conditioned to available stimuli. Through generalization and higher-order conditioning, a fractional form of the goal or consummatory response comes to be elicited by stimuli which antedate the goal. This fractional anticipatory goal reaction and the stimuli arising from it, i.e. $r_g - s_g$, are assumed to increase in strength along with the instrumental response, with continued reinforcement. While the instrumental response seems to develop to an asymptote rather quickly, it could be, as suggested by North & Stimmel (1960), that the fractional antedating response reaches its asymptote later (i.e. after more reinforcements) than does the instrumental response.

According to Hull, continuation of responding is inhibited somewhat by the accumulation, following each instrumental response, of reactive inhibition, I_R , which dissipates over time when responding is discontinued. The more rapid responding observed in the high-

reinforcement groups early during extinction should have resulted in a greater accumulation of I_R , so that their presumably greater original S^H_R soon would have been cancelled out, because of the subtraction of total inhibition from it, to give effective reaction potential,

$$\text{i.e. } S^{\bar{E}}_R = S^H_R \times C^1 - I_R - S^I_R.$$

Since I_R is conceived as a primary negative state, or a need to cease responding, its diminution is reinforcing. Thus any responses which are incompatible with the original conditioned response, thus preventing its emission, are reinforced by the reduction of I_R and become conditioned to the cues which precede them. These new modes of behavior, competing with the original conditioned response, represent the development of a habit of "not responding", S^I_R . This habit develops gradually, therefore dissipation of some of the I_R increases the probability that the original response will recur, with the consequent accumulation of more I_R and further strengthening of S^I_R . But S^H_R no longer is being strengthened so periodically recurring bursts of responding will be weaker because of interference from S^I_R which competes so successfully with S^H_R that the original response rarely occurs. In the present study, very few instrumental responses were emitted by the end of extinction, and twenty-four hours later, almost no spontaneous recovery of the original response tendency occurred.

In an attempt to describe events in relation to different temporal stages of extinction, Amsel (1958) has added to the Hullian inhibitory factors, I_R and S^I_R , an emotional factor which is another source of reinforcement for behavior incompatible with the instrumental

¹ A constant encompassing all the factors which multiply with S^H_R to determine reaction potential.

response. He has suggested that the experience of nonreward, in a situation which previously had been rewarding, creates a frustration effect (FE), which results in a temporarily increased drive level. This is manifested in types of behavior, e.g. biting the bar, exploration and hyperactivity, commonly considered indicative of frustration.

Since there is evidence (Wagner, 1959) that only after some minimal number of rewards will nonreward of a response be frustrating, frustration is conceptualized as being the result of an interaction between nonreward and a factor which has been developing during previous rewarded trials, this factor being the fractional anticipatory goal reaction ($r_g - s_g$) already mentioned. The stronger the $r_g - s_g$, based on previous rewards, the greater should be the FE resulting from nonreward (Amsel & Hancock, 1957; Amsel, Ernhart, & Galbrecht, 1961). Thus the present experimental groups which had received high numbers of reinforcements should have exhibited a more pronounced FE - a supposition which is consistent with their marked intensification in responding from the first to the third minute of extinction.

Since Amsel conceives of frustration as an aversive motivational condition, its reduction, like the reduction of I_R , can serve as a reinforcement to any behavior which interferes with the original response. With repeated approaches to the bar, the animal comes to anticipate the frustrative, "aversive" nonreward, so that a fractional anticipatory frustration reaction begins to develop in a manner similar to the earlier development of $r_g - s_g$. Since the stimuli (s_f) arising from the r_f are aversive, any behavior which enables the animal to avoid them is reinforced by frustration-reduction, and becomes conditioned to instrumental cues which antedate the goal.

But these same cues elicit $r_g - s_g$ which leads the animal toward the goal, so the two antedating conditioned responses are temporarily in competition. Since the goal response is no longer reinforced, but new responses are, by the reduction of both frustration and I_R , these avoidance responses eventually predominate over the original instrumental response. In other words, the original conditioned response is extinguished through the interference of the habit of not responding, s_{I_R} , which was frequently manifest, in the present experiment, through subjects' lying in a corner opposite to the bar.

The addition of the emotional factor of frustration seemed useful in accounting qualitatively for the type of behavior observed immediately upon withdrawal of reinforcement, as well as for the temporary increase in vigor of the conditioned response early in extinction. However, the effects of reinforcement which were apparent in the present data early in extinction appeared to wear off quite quickly. Therefore, designation of habit strength in terms of total number of responses in extinction obscured the fact that continuing extinction effects occurred at much the same rate regardless of the number of conditioning reinforcements. It seems that response persistence in extinction is not the important factor in the measurement of habit strength. It is not clear that subjects having experienced large numbers of reinforcements will "resist" extinction longer than those having experienced relatively few reinforcements. Rather, temporary differences in number of responses emitted per minute may differentiate these subjects early in extinction. Therefore, attempts to describe mathematical functions relating extinction responding to number of reinforcements probably should be based upon measures of response rates

early in extinction, when the effect of conditioning reinforcements seems to be greatest.

There remains the question of the nature of the function relating extinction responding to number of reinforcements. Although the overall trend was for increases in extinction responding to be associated with increasing numbers of reinforcements, there was some support to the notion (Finger, 1942b) that maximum resistance to extinction occurs following fairly few reinforced trials. (Statistical calculations quite consistently differentiated the controls and the 4-reinforcement group from the remaining higher-reinforcement groups which were generally non-differentiated statistically.)

Of greater interest is the indication that the function is non-monotonic. The 88-reinforcement group consistently displayed a stronger response tendency, apparently stronger than the 108-reinforcement group, though the difference between these two groups failed to reach statistical significance. This observation paralleled those of a number of recent studies - none involving operant bar-pressing - which suggested that a non-monotonic function relates extinction responding to amount of training (Senko, Champ, & Capaldi, 1961; Murillo & Capaldi, 1961; North & Stimmel, 1960).

North & Stimmel (1960) have tried to account for their findings of decreasing resistance to extinction of a runway response, from 45 to 90 and 135 reinforced trials, in terms of Amsel's frustration concepts. They assumed that the instrumental response reached its maximum strength within 45 reinforcements but that r_g did much later, perhaps between 90 and 135 reinforcements. Since r_f depends upon the strength of r_g , the latter groups, upon withdrawal of reward, should

have experienced more frustration and a stronger r_f . Therefore these groups should have extinguished more rapidly than the 45-reinforcement group. The authors suggested that a group which may have experienced a very small number of reinforcements, e.g. 10, also would have extinguished in relatively few trials because habit strength would have been relatively small.

The observation that increased training results in decreased resistance to extinction (Capaldi, 1957; 1958) has been related to the observation that overtraining also facilitates learning of a new response in some situations. Capaldi & Stevenson (1957) trained rats on a black-white discrimination to three successive criteria before re-training with reversed cues (if black was previously reinforced, it became the negative stimulus and the white became the positive one; and vice versa). While all three groups performed similarly at first, the most highly trained group soon became differentiated from the other two by a significantly faster decline in errors. The authors hypothesized that, following many reinforcements, the change in the reinforcement pattern is greater than for subjects experiencing fewer reinforced trials. Therefore, extinction of the original response should be fastest for the most highly trained subjects, allowing for fastest acquisition of the new response, i.e. reversal of responding to the opposite cue. It might be that frustration, due to nonreward, could facilitate such rapid learning of a new response to the extent that it facilitates rapid extinction, i.e. the reversed response could be considered just one more response which is incompatible with the original one, and is strengthened both by primary reinforcement and by the reduction of frustration arising from nonreward of the original response.

Reid (1953) also trained albino rats on a black-white discrimination, and noted that after stimulus reversal, the greatest number of repetitions of the original response, but also the fastest learning of the new response to the reversed cues, occurred in the most highly trained groups. He suggested that in relatively early stages of learning, an animal simply learns to make the response required to obtain reinforcement, but with increasing amounts of training, the animal learns to respond to the whole set of stimuli of which a specific subset are relevant, in the sense of procuring reinforcement. His highly-trained animals learned to look at the black or white stimulus before responding. Those with less training instead responded in terms of position habits and to irrelevant stimuli, other than the black and white cards.

More recently, Brookshire, Warren, & Ball (1961) investigated the influence of overtraining on response reversal within a stimulus continuum, as well as on transfer between dimensions - specifically, response learning (left or right turn) in comparison with place learning (response to black or white). The authors maintained that neither Reid's nor Capaldi & Stevenson's hypothesis was upheld, even though empirical observations were the same, i.e. for rats, overtraining facilitated response reversal. It did not affect inter-dimensional transfer. If rats learn to make discrimination responses to a set of stimuli varying within a single dimension, Reid's hypothesis should predict that inter-dimensional transfer should be hindered by overtraining. But, according to Capaldi & Stevenson's position, overtraining should facilitate both inter- and intra-dimensional transfer, since extinction of the original habit would still be more rapid following

overtraining. Brookshire, Warren, & Ball suggest that all the observations might best be described in terms of Lawrence's (1949) hypothesis that with overtraining, cues along a given stimulus dimension become more "distinctive", i.e. a change in the perceptual properties of stimuli operates to facilitate future discriminations along that dimension, but does not influence transfer to another stimulus dimension.

Responding during extinction, and on transfer, both inter- and intra-dimensional, following a wide range of amounts of training on problems of various difficulty, should be further investigated, to test both the reliability of observed effects of overtraining, and the several hypotheses which have attempted to account for these effects.

Summary

The purpose of this investigation was to ascertain to what extent "resistance to extinction" is a function of conditioning reinforcements when spurious responses are not recorded. In order to minimize spurious responses, a very inconspicuous bar was used. After extensive pretraining, each of 120 male rats was allowed 0, 4, 12, 36, 88, or 108 reinforced bar-presses. Extinction over 2 or 4 hours occurred the following day. Number of responses per minute differentiated groups primarily during the first 6 minutes of extinction, though a significant effect of reinforcements was apparent throughout the first hour. The results were related to constructs of frustration and inhibition. The interaction between reinforcements and time, i.e. the highest contingency between extinction responding and number of reinforcements was between 1 and 3 minutes and decreased thereafter, as well as the trend for the 108-reinforcement group to exhibit less resistance to extinction than the 88-reinforcement group, question the common use of resistance to extinction as a measure of habit strength. These results suggest a need to further investigate the nature of the extinction function over a wide range of reinforcements and times, and perhaps to revise the usually assumed relation between persistence of a habit and number of conditioning reinforcements.

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